# 9. Annex

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# 1. Introduction

Since ancient times, there has been an evolution in the methodology of construction and understanding of the building. This evolution has always looked forward to improve working methods, materials used, comfort... achieved, taking into account getting quality at a reasonable price.

On this evolution, safety has never been the main concern and throughout history has always been in the background. Today, it is not posible to keep on this point of view because security is an issue as important as the rest. Nowadays the society is very worried about job security in all areas, not only the building, and it is not acceptable, for example, that people can die in the building process.

After that, this paper aims to analyze, from the point of view of prevention, ceramic elements used in construction. This analysis is divided into next three parts:

a) The first part is centred on analyzing ceramic elements used in construction from a technical standpoint.
b) The second part tries to identify the occupational hazards of all the stages in the building process. A detailed study including the description and causes of risks will be the main objective of this second part.
c) Finally, the third part is a proposal of preventive and protection measures for these risks..

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# 2. Objectives

This document should be used as a guideline for the prevention of risks to those building engineers who work treating ceramic components. The document must contain a description of ceramic elements so the reader can acquire those concepts that will help on the way of understanding the risks to prevent. This detailed description will occupy the first of three parts in which the project will be divided.

The engineer must find a complete reference on identifying all potential hazards around the work with ceramic components. This reference should be enough so as not to need other sources and this way speed up the work of the engineer and to avoid any risk of accidents due to ignorance. The second of those three parts in which the document is divided will contain this work reference in a clear and detailed way using a description of each risk and explaining their causes.

In addition to the identification of risks around the ceramic components, this document will also propose measures for its prevention. These preventive measures will close the third and final part that divides this work. The implementation of the measures that are in this block must be sufficient to prevent all the described risks. The proposed measures will be ergonomic, organizational or security measures. In addition, there will be a collection of types of protection required to work (both individual and the collective).

Reading this document should be clear and understandable for anyone to avoid accidents from the misinterpretation of a risk or a preventive measure. This study is going to be accurate and is not going to give rise to doubts, so an accident is never attributable to an erroneous explanation of a risk or a measure. The reader should be aware that the workers safety is what we are talking about and it is a very important issue.

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# 3. Ceramic materials and components

## 3.1. Definition of ceramic material

Piece or pieces that are formed of a mixture of different types of clay, and other components, are then shaped and finally subjected to a cooking process.

The industry of mankind is possibly the oldest industry of the history. The manufacture of the first brick began in those countries where the stone was scarce and the clay was abundant. The first bricks were made of clay paste with pieces of straw to give consistency to those bricks.

The raw materials used for the preparation of ceramic pieces are:

a) Clays: Clays are sedimentary rocks from the disintegration of other types of rocks. The continuous action of atmospheric agents on the rocks causes the breakdown of these rocks and then appears the clay.Often these clays are altered by actions exerted on them during their consolidation (temperature, pressure …). Instead there is a variety according to their composition.
b) Water: We should control the content of soluble salts in these waters to prevent the occurrence of efflorescence.
c) Degreasers: Degreasers aren't plastic materials. They eliminate the plasticity of the clay because they open pores and improve drying. These degreasers are used to solve the problems of the greasy clay.

### *Classifying ceramic materials*

The classification of ceramic materials can be made according to different parameters (cooking temperature, type of clay...). The most widely used classification is according to the finish:

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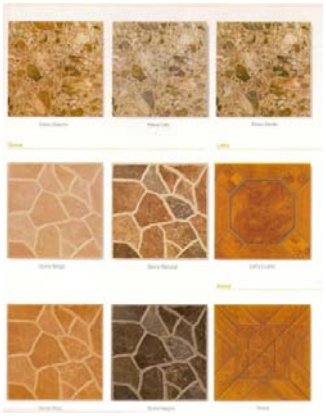
- Porous coarse ceramic: They are all products which have a rough or granulated touch. Examples: bricks, tiles…



- Vitrified ceramic: they have a compact structure, being porous or vitrified, but always waterproof. Examples: porcelain, stoneware...

## 3.2. Facades with ceramic elements

### *Definition of facade*

The facades are households, their main function is to protect the interior of buildings from external agents. For example: hot and cold temperatures, wind, noise... To do a structural function is not their purpose, but they can do it anyway (bearing walls). In this case we would be talking about walls resistant to closure.

The facades as external elements and visible from outside of the building have been a reflection of cultural and aesthetic changes as well as the development of habits of users. They are also the first part of the building of being seen.
Requirements of a façade

**The requirements are:**

- Protection requirements: Against water, wind, against the outside temperature, noise, fire and against intrusion.
- Comfort requirements: Visual comfort, aeration and contact with the outside.

### *Types of facades with ceramic elements*

- **Homogeneous facade**

In the very past, the closures consist of a single thick sheet, using a single material or some combination of materials. Usually the closures were protected with appropriate facing (inside and outside).

This facade walls have survived as homogeneous constructions until the early century XX., responding to the sealing and thermal protection and mechanical strength requirements with sheet, a minimum of 30 cm in the case of ceramics.

Only for a particularly cases (need sealing in exposed situations) we used facades with special overlapping layers or composite.

Nowadays as facades of one sheet can be found:

a) Facade with block "termoarcilla":

This type of facade, contrary to what is built today, consists of a single sheet, fulfill the required requests.

In buildings of low height and minimal load, the thickness will be determinate by the thermal and acoustic requirements. The minimum thickness is 19 cm.

- **The composed or heterogeneous facade**

Following the modern movement, the spread of concrete and steel structures give the facades the only function of closure.The thermal and sealing protection can guarantee with a proper composition constructive.

In the early XX century the simple closures evolve to thinner walls. Later appears composed walls with several layers.

The types of facades that are constructed of ceramic materials are:

- **Traditional facade:**

The traditional facade is the more widespread in Spain. This facade consists of:

a) The outer part, which is solved by bricks and resting on the slab on each floor. In case of not seen bricks is necessary to apply facing because the main mission of the outer part is waterproofing the closure.

   It is important to consider the stability of the outer part. With the size of regular bricks, it is difficult if you want to pass ahead of forged. This can solved, for example, having a metallic profile height of support forged.

b) The air chamber, which is usually about 10 cm. Inside of this a thermal insulating material is placed.
c) The inner part, which protects the insulating material from the inside, closes the air chamber and supports the lining. Mission can also be structural if it is a load-bearing wall.

- **Ventilated facade**

The ventilated facade appears because the people demands quality of the facade and the depletion in the evolution of the traditional facade.

The ventilated facade is indented to improve the performance of the conventional facade respect to the thermal protection, sealing, stability and utility limitations.

The typical constructive solution is a ventilated air chamber across the entire facade. Its mission is to close the passage of water and evacuate the humidity with the continue ventilation. It also incorporates a thermal insulating material and an anchoring system for the siding.

The outer face of the building is not based directly on the structure of the building. The anchoring system will fix the structure.

The inner part rests directly on the internal structure of the building.

The ventilated facades provide protection to the buildings from atmospheric agents, producing different effects depending on the weather seasons. In summer, avoid the overheating of the exterior preventing that the temperatures inside of the building rises. In winter, this trend is reversed and it is the building that warms the outside air.

Other advantages of ventilated ceramic facades are that the surround system will be lighter and the freedom of choice of coating material in highest qualities.

**- Double walls (cavity wall and septum rain)**

It consists of two walls with an intermediate air chamber. These walls might fulfill a structural function and are fixed using braces. The maximum height is limited to 3 floors.

The inner wall is in contact with the different concrete slab and in case of a structure bearing walls, it will bear the weight of the floors. The outer wall passes freely without binding against the concrete slab, except in cases where there are overhanging. This way, the problem of thermal bridges gets avoided because there are no interruptions in the outer wall.

This type of wall is very similar to the cavity wall, a facade solution very used in England.

**- Trans ventilated facades**

They are solved by using studs, crossbars and closures. The studs are anchored to the walls of factory and the closures pieces are quite relevant to the weight. They are usually plates made of stone or pottery.

This type of walls is used, for example, on institutional buildings to provide a higher quality result.

## *Most singular points in a facade*

For the construction of each type of facade will find some points that need to be more complicated to deal with special care because if it not be solved can cause some problems (pathological, structural ...)

- Support of the the outer part on the concrete slab (if any): sometimes depending on the size of the pieces is difficult to support the leaf. At this point there will not be a continuous insulation.
- Joining with the footing: We should be careful at this point because the resolution of these diseases is very expensive. We try to prevent the capillary rise of water.
- Holes resolution (lintels): It is considered one of the weaknesses of closure because it decrease the thermal and acoustic insulation. Their sealing should be resolved in the windows and in union with ceramic wall. In addition, the position of holes should be well studied.
- Finish top: It is a delicate point because it is exposed to atmospheric agents. It is important to know the type of roof, without forgetting the security necessary to prevent contact of water on the facade.

- Tightness of the wall: We have to fill the joints, especially vertically, as when there are moisture problems, the reason is the lack of mortar in this joints.

## *Pieces used for building facades with ceramic elements*

- Brick face side, solid and perforated: It is the brick with vertical holes which may be solid or perforated under the terms of CTE. The brick face side is commonly used in conventional brickworks with brick joins, around 1 cm or 1.5 cm, being assured the resistance and the tightness when the mortar is penetrated by the holes to get a perfect adhesion between both materials.

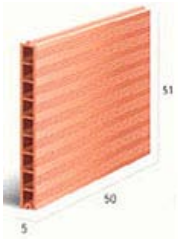
- Brick and Brick Sound: These are the bricks with vertical holes that can be massif (between 0% and 25% of drilling), perforated (between 25% and 45% perforation) or hollow (between 45% and 60% drilling under the terms of the Technical Building Code). It is used on brickworks with conventional (brick joins), around 1 cm or 1.5 cm, being assured the resistance and sealing, when the mortar gets penetrated through the holes and it gets a perfect adherence between both materials.

The bricks are manufactured traditionally in two formats: as measured in Spanish or metric and the Catalan way.

- Block Termoarcilla ®: They are hollow blocks with perforations between 25% and 45% according to the classification of the CTE. Termoarcilla ® is a low density ceramic block, with special characteristics that place this material as better than other existing materials in the market.

- Small format pieces (Hollow block): It is the brick with horizontal drillings generally superior to 60% under the terms of the CTE. Commonly used as walls or party walls and inner part in constructive solutions of facades.

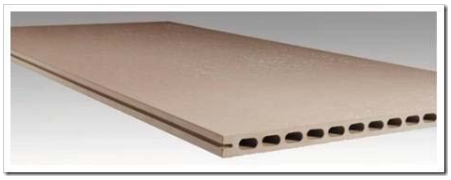
- Large format pieces: Hollow bricks dimensionless than 140 mm. are called large format pieces, length exceeding 300 mm. and thickness equal or greater than 40mm. It is used as a partition wall element or inner layer of facade constructive solutions.



## *Materials of finishes for facades*

"Azulejo": ceramic piece of little thickness, generally square, where one side is glazed, the result of the firing of a substance with enamel that becomes waterproof and shiny. This face can be monochromatic or polychromatic, smooth or embossed. They are generally used in large quantities as an element of interior or exterior surface coating or as a decorative element in isolation.

Mosaics: Pieces of very small size. They are usually between 1.5 and 3 x 1.5 cm x 3 cm



- Ceramic Plates: They use to be large parts formed by their aesthetic qualities and by very good technical characteristics, although they also can be found in small format.

| **Types of facades** | **Outer Part** | **Inner Part** |
|---|---|---|
| Homogenous Facade | Solid or perforated brick face side | It hasn't got. |
| Facades with only one layer with termoarcilla blocks | Termoarcilla block<br><br>**Type of finish:** "Azulejos", mosaics and ceramic plates | It hasn't got. |
| Traditional facade | Solid or perforated brick face side<br><br>Perforated brick with finish format.<br><br>**Type of finish:** "Azulejos", mosaics and ceramic plates | Large format pieces<br><br>Small format pieces |
| Ventilated facade | Solid or perforated brick face side<br><br>Perforated brick with finish format<br><br>**Type of finish:** "Azulejos," mosaics and ceramic plates | Large format pieces<br><br>Termoarcilla Block<br><br>Small format pieces |
| Double walls | Solid or perforated brick face side<br><br>Perforated brick with finish<br><br>**Type of finish:** "Azulejos", mosaics and ceramic plates | Large format pieces<br><br>Small format pieces (brick and super brick) |
| Trans ventilated Facades | Ceramic Plates | Termoarcilla block<br>Small format pieces (brick and super brick) |

## 3.3. Partition walls (interiors and party walls) with ceramic elements

### *Partition wall definition*

They are vertical elements that make up the subsystem of compartmentalization of interior space, separating different local or stays together. Generally they have no structural function, but we find them acting as such, joining the walls of cargo.

### *Partition wall requirements*

The partition wall requirements are:

- Stability: The partition wall should be stable by itself.
- Fire resistance: If the wall has a certain fire resistance will help slow the spread of fire inside the building.
- Thermal Insulation: For better thermal comfort inside the rooms the partition walls must have more or less insulation depending if they are communicating with colder areas of building.
- Acoustic insulation: It must prevent the transmission of the noise to isolate the different zones that may exist in the building.

### *Types of partition walls with ceramic elements*

Removable partition walls: are those which can vary its position without changing their properties depending on its use, for example tends to occur in office buildings that are not usually constructed by using ceramic materials.

Fixed partition walls: are those that remain unchanged throughout the life of the building such as residential buildings. The ceramic fixed partition walls types are next:

- Partition wall type 1(<10)

Used in the walls of the same property or premises, except for those bordering wetlands, such as kitchens or bathrooms. They may include installation of water when these do not exceed 2 cm in diameter.

- Partition wall type 2(>10)

It is a fixed partition wall of more than 10 cm of thick that is used to separate wetlands. It may include in its thickness any water pipe used in the house.

- Partition wall type 3(>10)

Depending on the type of brick used and the function they perform this type of partition wall could be:

a) With small format pieces (Hollow block): Used to separate modules of rooms in hotels, nursing homes and hospitals, so it will not be the type of wall that is commonly used in houses.
b) With solid and perforated brick: Fundamentally used to separate local and adjacent houses. It also is used to separate common areas in a home, modules of rooms in hotels, nursing homes, hospitals, offices and shopping centers.

### *Most singular points on a partition wall*

For the construction of partition walls will find some points that need to be more complicated to deal with special care because if it not be solved can cause some problems (pathological, structural ...)

- Joining to other subsystems: It should be noted that the wall joining to the ceiling and the floor and sometimes with the facade of the building. These joins should be resolved.

- Holes resolution (lintels): It can be considered a weakness in the wall. Usually we find in the walls doors.
- Building installations: The houses should incorporate different facilities: electricity, water, gas, telecommunications ... The tour of these building installations frequently pass through the interior of partition walls. We must be provided where the building installation pass.

## *Used pieces on the partition walls building using ceramic elements*

- Small format pieces (hollow brick)
- Large format pieces
- Solid and perforated brick

| **Type of partition wall** | | **Material** |
|---|---|---|
| Partition wall type 1(<10) | | 7,5 cm brick<br><br>Large format pieces |
| Partition wall type 2(>10) | | min. 10 cm of width brick |
| Partition wall type 3(>10) | With small format pieces (Hollow block) | 7,5 cm brick<br><br>Large format pieces |
| | With solid and perforated brick | Solid or perforated brick |

## 3.4. Roofs with ceramic elements

### *Roof definition*

The roofs are top closure structures that are used as external closures. Its main function is to provide protection against climatic agents and other factors to the building and shelter him, give privacy and provide sound and thermal insulation, like all other vertical walls. The roofs also must be considered as a structural element that support its own weight and loads acting on itself (use, wind, snow, street vibrations...), moving this efforts to all resistant elements of the building.

Tipically roofs are composed by three parts:

- The exterior surface finish: It's in contact with climatic agents.
- The intermediate layers: They isolated and waterproof the roof.
- The supportt: This part supports the outer surface finishing and the intermediate layers.

### *Roof requirements*

- Waterproof: Water can not pass inside the building through the roof.
- Wind insulation
- Capture an dissipation of energy: The roofs must be well prepared in case of thunderstorms.
- Thermal, acoustic and lighting comfort: To guarantee a good insulation to get this comfort.
- Structural fire safety: To guarantee fire resistance to help slow the spread of fires.
- Durability and maintenance: The roof must be enabled for maintenance because of that it will have better durability
- Installations and structure compatibility: The roof must incorporate building installations. It should not impede the smooth functioning of the roof. In addition the union of this structure should not interfere in the functioning of two systems.

## *Types of roofs with ceramic elements*

The types of roofs can be divided by: flat roofs and pitched roofs.

Flat roof: The one that has slope less than 5 %. The elements in the flat roof are:

- Structure support: Usually the last concrete slab on the build.
- The slopes: Its obtained with the material.
- Separator layers: used to extend the life of the materials of the roof, inserting it.
- Waterproofing: is the layer that provides sealing to the roof.
- Finishes and protective elements. (It is the ceramic element).

In this roof typology we can find passable roofs and not passable roof.

a) Not passable roof: Those that are only used to maintenance the roof. Usually for the construction of this type of roof ceramic elements are not used.
b) Passable roofs: are those who possess a protective layer. This layer allows pedestrian or vehicular traffic to the surface. In this kind of roof with ceramic elements will find the final finish of the roof.

Within this type of roof which has a ceramic finish are:

- Ventilated roof "a la catalana": It has an air chamber to create air currents that attenuates high temperatures in the upper roof. It has a very low slope, between 1% and 3%. The finish is usually ceramic.

- Passable roof (hot): It is a kind of inverted roof because the insulation is placed on the waterproofing.
  The slopes are recommended between 1 % and 3%. The finish material can be ceramic.

Pitched roof: It has a slope roof with more than 10%. It is a constructive solution based on a slope, comprising different inclined plans that favor the removal of overlapping water. These inclined planes are joined with small pieces for protection.

The elements in the pitched roofs are:

- Structure support: Usually the last concrete slab on the build.

- Insulation: To guarantee the thermal comfort inside the building.
- Finishes and protective elements. (It is the ceramic element)

The pitched roof with ceramic elements most used is tiles roof. This kind of roof is very used in Mediterranean areas. The roof tiles are arranged perpendicularly to the peaks and overlap between them.

### *Most singular points on a roof*

For the construction of roofs will find some points that need to be more complicated to deal with special care because if it not be solved can cause some problems (pathological, structural...).

- In flat rooofs: ventilation ducts, antennas, expansion joints, sinks...

They can cause leaks water and overloads on the roof that can break pieces.

- In pitched roofs: ventilation ducts, canals, crown of the roof, meeting surfaces...

They can also cause leaks water that can break pieces.

### *Pieces used for building roofs with ceramic elements*

- Ceramic roof tiles: The baked clay tiles are elements which are placed on discontinuous pitched roofs and on walls. It's obtained by forming (extrusion and/or pressing), drying and baking clay (containing or not additives).

  The types of roof tiles that we use are:

  a) Barrel tile: It is one piece with cone trunk shape, cut in half length wise. With this piece can be solved all the problems of a roof.

  b) Flat tile: It has more complex form. The shape of the roof tile allows it fit and overlaps. Requires special pieces to resolve some parts of the roof.

c) Pantiles: It is 'S-shaped' in appearance and is single lap, meaning that the end of the tile laps only the course immediately below. Requires special pieces to resolve some parts of the roof.

d) Special pieces:


e) Ceramic tiles: Are used in flat roofs. There is a wide variety of models and sizes because of the high technology development in the fabrication of tiles.

| **Tipes of roofs** | **Material** |
|---|---|
| Ventilated roof "a la catalana" | Ceramic tiles |
| Passable roof (hot) | Ceramic tiles |
| Pitched roof with roof tiles | f) Barrel tile<br>g) Flat tile<br>h) Pantiles |

## 3.5. Concrete slabs with ceramic elements

### *Definiton of concrete slab*

The concrete slab is a structural element, usually horizontal, capable of transmitting burdens that it supports and its own weight to other structural elements (pillars, walls…).

It's part of the horizontal structure, allowing not only transmit vertical burdens, also horizontal burdens

### *Concrete slab requirements*

The requirements for concrete slabs are:

a) Structural functions: They must resist loads and transfer them to the supports without excessive deformations.
b) Rigidity condition: They should absorb vibrations and transfer efforts of the wind.
c) Sound resistance: They should ensure resistance to noise impact that can cause the concrete slabs
d) Thermal resistance: Especially in areas not covered and heated.
e) Fire resistance: If the wall has a certain fire resistance will help slow the spread of fire inside the building.

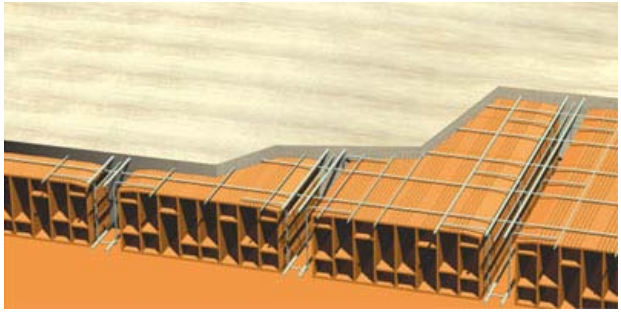
### *Types of concrete slab with ceramic elements*

By the way of transmitting the burdens can be classified the concrete slabs in two types:

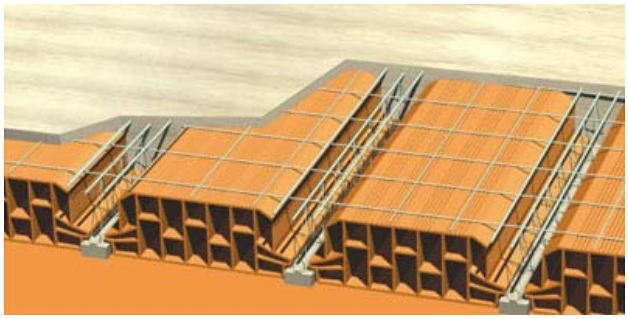
a) One way slabs: needs moment resisting reinforcement only in its short-direction. Because, the moment along long axes is so small that it can be neglected.

   The one way slabs with ceramic elements are:

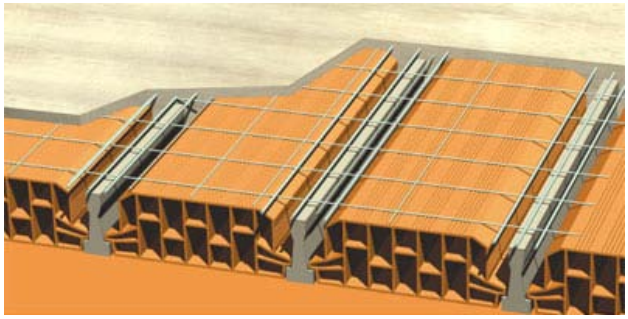
   - In situ one way slab: In situ concrete slabs are built on the building site using formwork.



- One way slab with reinforced joists (prefabricated joist)



- One way slab with prestressed joists (prefabricated joist)



b) Two way slab: needs moment resisting reinforcement in both directions. It can support on linear elements (joists, walls) or on point.

The two way slabs with ceramic elements are:

o In situ two way slab: In situ concrete slabs are built on the building site using formwork.

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## *Most singular points on a concrete slabs*

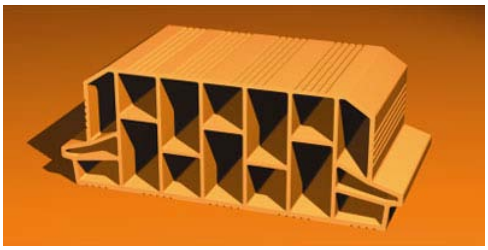
For the construction of roofs will find some points that need to be more complicated to deal with special care because if it not be solved can cause some problems (pathological, structural...)

a) The point where concrete slab and façade join: Depending on the size of the pieces it is difficult to support the pieces of façade on the concrete slabs. We can not always get a continuous insulation.
b) Expansion joints: Sometimes we need to place expansion joints in the concrete slabs to avoid breaking them.
c) The point where pillars and concrete slabs join: We should join the concrete slabs reinforcements and pillars reinforcements to obtain proper transmission of loads.
d) Realization of gaps (stairs): It can be considered a weakness in concrete slabs. This area needs reinforcements.
e) The point where concrete slab and roof join: Water can not pass inside the building through the roof. The concrete slab should be waterproofed.

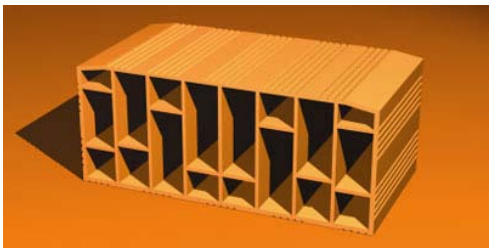
## *Pieces used for building concrete slabs with ceramic elements*

- Ceramic filler block:

a) Ceramic filler block



b) Rectangular ceramic filler block



c) Rectangular ceramic filler block (encegada)

| **Types of concrete slab** | **Material** |
|---|---|
| In situ one way slab | Rectangular ceramic filler block |
| One way slab with reinforced joists (prefabricated joist) | Ceramic filler block |
| One way slab with prestressed joists (prefabricated joist) | Ceramic filler block |
| In situ two way slab | Rectangular ceramic filler block |

## 3.6. Claddings with ceramic elements (walls and paviments)

### *Cladding definition*

Claddings are the superficial finishes that help on continuity and are used for decorating and protecting. The claddings also protect to surfaces from atmospheric agents.

### *Claddings requirements*

a) They must offer security: Repairs will be needed if there are many landslides. There will be a large expense in the maintenance of these claddings.
b) Preventing cracks: Aesthetically it is not recommended that arise fissures, these fissures can cause also landslides.
c) Adequate placing of expansion joins: They must be placed properly to prevent landslides and fissures in the cladding.

### *Claddings typology with ceramic elements*

Claddings of pavements: Superficial finish of the horizontal base of a construction that is used for supporting people, furniture, etc.. There are different types of pavements:

1) Vehicular traffic surface: Cladding made by pavers placed on a sand layer capped. Its width varies between 3 and 5 cm. It is used generally at urban zones on low-level of traffic or on low velocity zones of circulation because of its lower deformability and greater durability.

2) Interior pavements: Discontinuous pavement at interior zones as residential zones, commercial centers, industrial…
3) Exterior pavement: Discontinuous pavement of exterior pavements as balconies, yards and terrace.

Cladding of walls: Superficial finish placed on pavement base of manufacture or concrete block:

1) Interior wall claddings: Discontinuous claddings of surfaces at interiors of residential zones, commercial, industrial... Sockets are also included.
2) Exterior wall claddings: Discontinuous claddings of surfaces at the exterior of facades.

### *Most singular points of a revetment*

a) Base regularity: We get a flat base so that the materials adhere properly and avoid landslides and fissures.
b) Joints execution: We should make them to facilitate the placement of the pieces.
c) Doors and windows placement: We must take into consideration the situation of these doors and windows to make a proper distribution of these pieces.

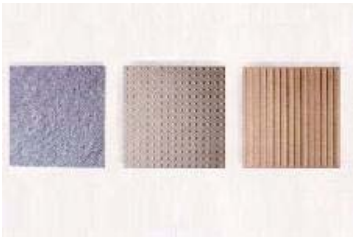
### *Pieces used on the revetments construction with ceramic elements*

a) Ceramic tiles: Thin ceramic piece, usually squared. One of its faces uses to be glazed, and it is the result of firing a substance using enamel that turns shiny and waterproof. This face may be monochromatic or polychromatic, smooth or embossed. They use to be pieces with high water absorbency, cold pressed, made by single firing or double firing.

b) Pavers: Prismatic pieces prefabricated made by concrete or ceramic, allowing its joint with others by its geometry to get a continuous surface.

c) Stoneware tiles: Ceramic tile with low or medium-low water absorption, dry pressed, enamel and manufactured generally by single firing.

d) Ceramic floor tiles: Ceramic tiles with very low water absorption, dry pressed, not enameled and then manufactured by single fire.



e) Ceramic tile: Tile with medium-high or high or very high water absorption, extruded, generally not enameled and manufactured also by single fire.

f) Rustic tile: Ceramic tile with low-medium or medium water absorption and extruded, generally not enameled.

g) Socket: This is an inner frieze of a wall, or inferior member of a pedestal.

| **Revetment types** | **Material** |
|---|---|
| Pavement of pavers prefabricated | Prefabricated ceramic tiles |
| Interior pavements | Stoneware tiles, porcelain tiles |
| Exterior Pavements | Ceramic tiles, rustic tiles, porcelain tiles, stoneware tiles pavement |
| Interior wall revetment | Ceramic tiles, porcelain tiles, sockets. |
| Exterior wall revetment (facades) | Rustic tiles, porcelain tiles, stoneware pavement |

# 9. Annex

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